OAK RIDGE NATIONAL LABORATORY
Operated By
CARBIDE AND CARBON CHEMICALS COMPANY
UCC
POST OFFICE BOX P
OAK RIDGE, TENNESSEE

DATE: November 5, 1952

COPY NO.

SUBJECT: DESIGN OF A UNIT FOR THE REMOVAL OF IODINE FROM THE DISSOLVER OFF-GAS STREAM IN THE IDAHO CHEMICAL PROCESSING PLANT

TO: F. L. Culler

FROM: W. L. Carter

This Document consists of 33 pages. No. 42 of 50 copies. Series A.

DISTRIBUTION

1.	F. L. Steahly	17.	F. A. Hall, Amer. Cyan. Co., Idaho
2.	W. K. Eister	18.	F. A. Hall, " " " "
3.	F. L. Culler	19.	H. A. Ohlgren" " " "
4.	H. K. Jackson	20.	T. W. Clapper" " " "
5.	F. R. Bruce	21.	D. G. Reid " " " "
6.	W. B. Lanham	22-27.	N. J. Rigstad" " " "
7.	W. G. Stockdale	28.	E. P. Reichardt " " "
8.	W. L. Carter	29.	G. M. Smith " " " "
9.	H. O. Weeren	30.	A. C. Johnson, AEC, Idaho Oper.
10.	W. F. Schaffer	31.	H. M. Leppich " " "
11.	H. E. Goeller Idaho	32.	W. L. Ginkel " " "
12.	R. J. Klotzbach "	33.	R. I. Martens, DuPont, ORNL
13.	E. L. Nicholson "	34.	W. B. Watkins, " "
14.	A. M. Rom "	35.	C. E. Winters
15.	S. H. Jury	36.	H. L. Hull
16.	J. M. Holmes, Foster Wheeler, Idaho	37-50.	Central Files

ATC 4/3/95

P3731

[redacted]

Table of Contents

[redacted]

[redacted]

[redacted]

List of Figures

[redacted]

[redacted]

By: W. L. Carter

To: F. L. Culler

Subject: Design of a Unit for the removal of Iodine from the Dissolver Off-Gas Stream in the Idaho Chemical Processing Plant

Processing Off-Gas from MTR Fuel Element Dissolvings

For satisfactory operation of the system for processing dissolver off-gases in the Idaho Chemical Processing Plant, it is essential that fission product iodine and bromine be removed in the first stages of the system. If these elements are allowed to remain in the process gas, catalyst and adsorption beds in the latter stages of the system are susceptible to their poisoning effect with a resulting decrease in efficiency. In addition, the gamma radiation of I^{131} would present a radiation hazard throughout the system which would make operation and maintenance more difficult.

The method of iodine removal for this plant is based on the experimental work* of the Air Reduction Sales Company of Murray Hill, New Jersey, and on the subsequent plant scale operations at Hanford Works. A preliminary design survey for adapting this process for use in the Idaho Chemical Processing Plant has been reported by the Process Design Section in ORNL CF No. 51-3-27.

The process consists of passing the gas stream at an elevated temperature through a bed of ceramic porcelainized Berl saddles whose surface has been coated with silver nitrate. At this elevated temperature silver nitrate reacts with iodine removing it from the gas stream. Any bromine present will be removed in the same manner. Hanford** has determined that the optimum operating

*These results are presented in reports ARSC-18, ARSC-20, ARSC-25, ARSC-28 and ARSC-29.

**W. G. Stockdale's copy of letter dated 7/2/51 from V. R. Cooper of H.E.W. to L. C. Evans of du Pont; subject, Iodine Removal with Silver Reactors.

temperature for the iodine-silver nitrate reaction is 375°F. It was first reported by Air Reduction Sales Company* that 220°C (428°F) would be the optimum operating temperature; however, it was later found by Hanford that this temperature was too high, resulting in decreased efficiency. It should be pointed out that silver nitrate fuses at 212°C (413.6°F) and that it would, therefore, appear unwise to operate the reactor above this temperature. The surface coating could be destroyed very easily if the silver nitrate should melt.

Iodine removal efficiencies of 99.9% have been reported by Air Reduction Sales Company (ARSC-28) when operating at 428°F. Also it has been stated (ARSC-18) that this high removal efficiency can not be maintained throughout the life of the coating; when 30-40% of the silver nitrate has been reacted, the iodine removal efficiency begins to decrease. However, Hanford Works has been operating their plant scale units at 375°F and have found that 99.9+% removal can be attained at this temperature. In addition this efficiency has been maintained for a period of approximately one year's operation. In view of these facts it has been thought advisable to operate the Idaho Chemical Processing Plant units at 375°F instead of the previously suggested 428°F (ORNL CF 51-3-27).

The silver nitrate coating can be quite easily applied on the Berl saddles by flooding the packed section with two molar silver nitrate solution, draining the excess solution and allowing the packing to dry. This action will deposit approximately 6.3 grams $AgNO_3$ per sq. ft. of packing surface (ARSC-28).

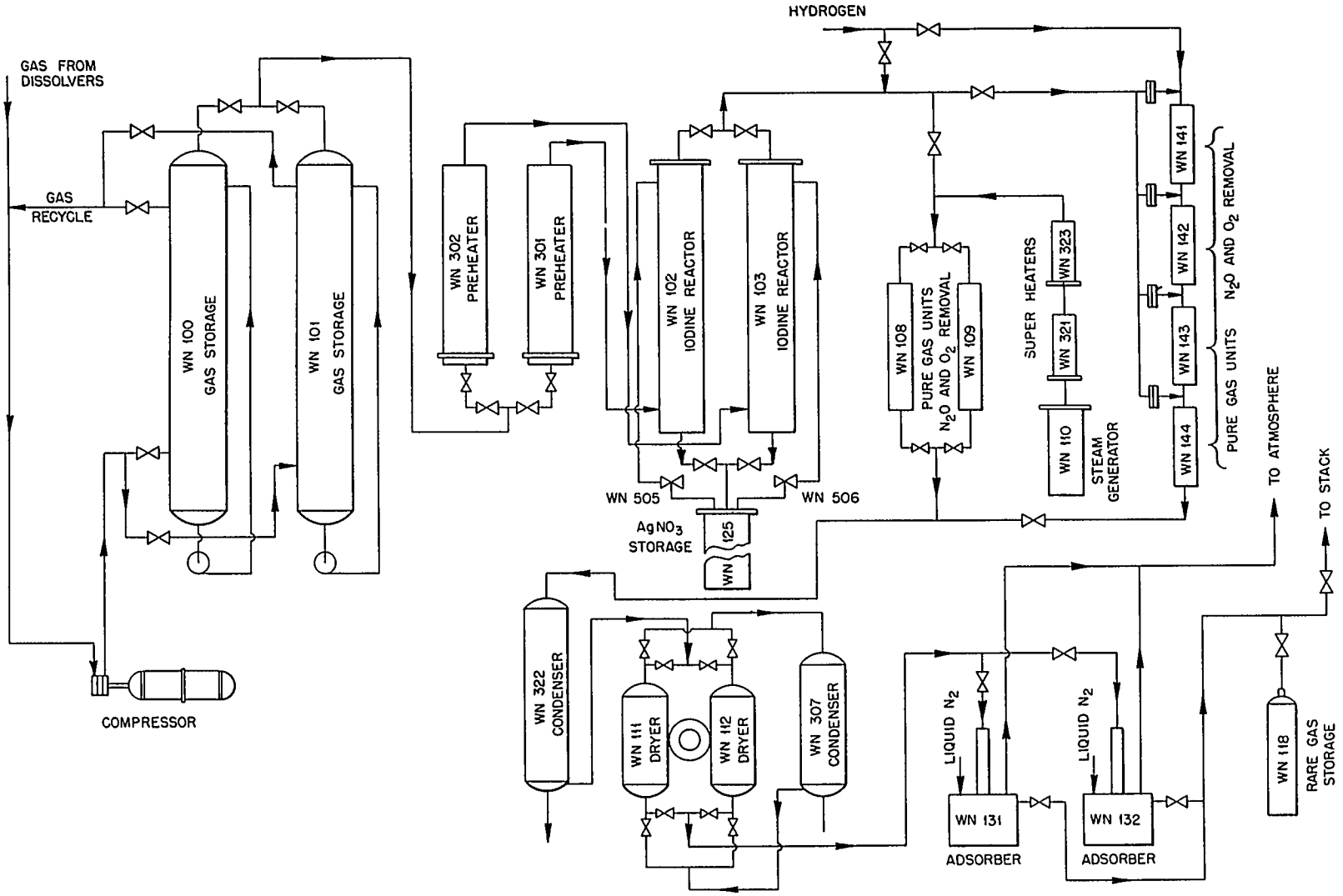
*Report ARSC-28

When iodine removal efficiency drops below 99.9%, the silver nitrate coating should be renewed. This can be accomplished by flooding the packed section a second time with four molar Ag NO_3, allowing the spent coating to dissolve and simultaneously deposit a renewed coating. It has been found (ARSC-25) that 4 gms. AG I will dissolve per 100 ml of four molar AG NO_3 solution. In order to facilitate storage of Ag NO_3 solution, only 4 M solution will be employed in the Idaho Chemical Processing Plant; initial and subsequent coatings will be applied with Ag NO_3 of this strength. Between regenerations the solution will be stored in vessel WN 125.

Duplicate reactors will be provided for the iodine removal system; this will allow the regeneration of one unit while the second unit is on stream. Each unit will be provided with a preheater for raising the gases to the reaction temperature (375°F); also each unit will be equipped with tubular heaters strapped to its outer surface to maintain a constant temperature in the reaction zone.

The position of the iodine removal units and preheaters in the dissolver off-gas processing system is depicted in Figure 1, page 7 . Complete construction details of the iodine reactors, designated as vessels WN 102 and WN 103, are furnished on ORNL Drawing No. 542-41V-2551A. The details of the silver nitrate solution storage vessel, WN 125, are furnished on ORNL Drawing No. 542-43V-2556B. The preheaters, WN 301 and WN 302, are Chromalox air preheaters, No. GCH-215, described in Chromalox Catalogue No. 50, pages 30-31. Tubular heaters, which are clamped to the outside of vessels WN 102 and WN 103, are General Electric Calrod heaters.

Drawing # 16983



DISSOLVER OFF-GAS SYSTEM
FIG NO. 1

Design Calculations for Iodine Reactors WN 102 and WN 103

The basis for design of off-gas processing vessels is to provide capacity for processing gases at a rate of approximately 4 SCFM.(a) At this rate all dissolver gases from 8 MTR batches, which is slightly more than one day's operation, can be processed in five hours.* Gases entering WN 102 and WN 103 come from the storage drums, WN 100 and WN 101, and have the following composition:

Gas	lb. Moles per 8 MTR Batches	Mole Fraction	lb. Moles per hour*	SCFM 32°F & 1 atm.*
N_2 + A	2.4840	0.7275	0.4968	2.9725
N_2O	0.4579	0.1341	0.0916	0.5481
O_2	0.2600	0.0762	0.0520	0.3111
H_2	0.0567	0.0166	0.0113	0.0676
CO	0.0059	0.0017	0.0012	0.0072
Radioactive				
I^{131}	4.808×10^{-7}		9.62×10^{-8}	5.75×10^{-7}
Xe^{133}	1.584×10^{-7}		3.15×10^{-8}	1.88×10^{-7}
Kr^{85}	1.832×10^{-5}		3.66×10^{-6}	2.19×10^{-5}
Non-Radioactive				
Br_2	9.093×10^{-6}		1.819×10^{-6}	1.09×10^{-5}
Kr	3.312×10^{-4}	0.0001	6.62×10^{-5}	3.96×10^{-4}
I_2	6.6×10^{-5}		1.3×10^{-5}	7.77×10^{-5}
Xe	0.00203	0.0006	0.0004	0.0024
Sub Total	3.2668		0.6533	3.9093
H_2O**	0.1474	0.0432	0.0295	0.1765
Total	3.4142	1.0000	0.6828	4.0858

*Based on 5-hour processing time. Design has been changed so that actual processing time is 7 hours.

**Saturation at 75°F

(a) In later design this rate was changed to approximately 3 SCFM.

Calculation pertaining to the values in the preceding tabulation may be found in reports ORNL C.F. No. 51-3-27, ORNL C.F. No. 51-7-90 and ORNL C.F. No. 51-10-36. Quantities of radioactive I^{131} were calculated on the basis of 30 days irradiation and 50 days cooling time of MTR assemblies. This is the shortest proposed cooling period; therefore, the largest quantities of I^{131} would result from these conditions. In normal operation it is expected that a cooling time of 120 days will be used.

An additional design requirement is to furnish sufficient $Ag\ NO_3$ capacity to permit extended periods of operation between regenerations. Four to six months operation before regeneration appears to be a convenient cycle to use.

On the basis of 8 MTR batches, the total components that react with $Ag\ NO_3$ are

I^{131}	=	4.808×10^{-7} lb. moles	=	9.616×10^{-7} lb. atoms
I	=	6.6×10^{-5} lb. moles	=	$1320. \times 10^{-7}$ lb. atoms
Br	=	9.093×10^{-6} lb. moles	=	181.86×10^{-7} lb. atoms
		Total		1511.476×10^{-7} lb. atoms

$$Ag^{+} + I^{-} = Ag\ I$$
$$Ag^{+} + Br^{-} = Ag\ Br$$

One silver atom will react with each atom of iodine on bromine; therefore,

$$\text{Wt. } Ag\ NO_3 \text{ required} = 1.511 \times 10^{-4} \text{ lb. moles} \times \frac{169.88 \text{ lbs.}}{\text{lb. mole}} \times \frac{453.6 \text{ gms}}{\text{lb.}}$$

$$= \frac{1165. \text{ gms.}}{8 \text{ MTR batches}}$$

It was arbitrarily decided that a reactor having the following dimensions would be a convenient size:

*Diameter	=	10 in.
Height	=	10 ft.
Volume	=	5.45 ft^3
Packing	=	1/2 in. Berl saddles

*In the final design the inside diameter was made 9 3/4 in.

One-half inch Berl saddles have a surface area of 134 ft^2/ft^3. The total surface area in the above reactor is

$$A = 5.45\ ft^3 \times \frac{134\ ft^2}{ft^3} = 730\ ft^2$$

As mentioned above 6.3 gms. Ag NO_3 will deposit on each square foot of surface from a 2 M Ag NO_3 solution. 4 M Ag NO_3 is to be used in this reactor, and the stronger solution should deposit a heavier coating. However, no figure is available for the density of a coating left by 4 M Ag NO_3, so the more conservative figure of 6.3 gms/ft^2 will be used

$$\text{Wt. Ag } NO_3 \text{ coating} = 730\ ft^2 \times \frac{6.3\ gms}{ft^2} = 4600 \text{ gms. on } 10.15 \text{ lbs.}$$

However, 99.9 % efficiency of iodine removal cannot be expected over the entire lifetime of the coating. As stated above, when the coating is 30-40% spent, the removal efficiency can be expected to drop below 99.9%. Therefore, the Ag NO_3 that will be effective is:

$$\text{Effective weight Ag } NO_3 = 10.15 \times 0.3 = 3.045 \text{ lbs.}$$

The number of MTR batches that can be processed before exhausting 3.045 lbs. Ag NO_3 is:

$$(3.045)(453.6) \text{ gms Ag } NO_3 \times \frac{8 \text{ MTR batches}}{11.65 \text{ gms Ag } NO_3} = 948 \text{ batches}$$

The proposed MTR assembly dissolving rate is 7.2 batches per day. At this rate

$$\text{No. days operation before regeneration} = \frac{948}{7.2} = 131.5$$

Residence Time of MTR Gases in WN 102 & WN 103

WN 102 and WN 103 will operate at the following conditions:

Temperature	=	375°F.
Pressure	=	11.84 psia
Gas Velocity	=	4.0858 SCFM (32°F & 1 atm.)
Inside diameter	=	9-3/4 in.
Packing depth	=	10 ft.

[redacted]

Free volume = (volume of 10 ft. section)(fraction voids of Berl saddles).

1/2 in. Berl saddles are 68% voids.

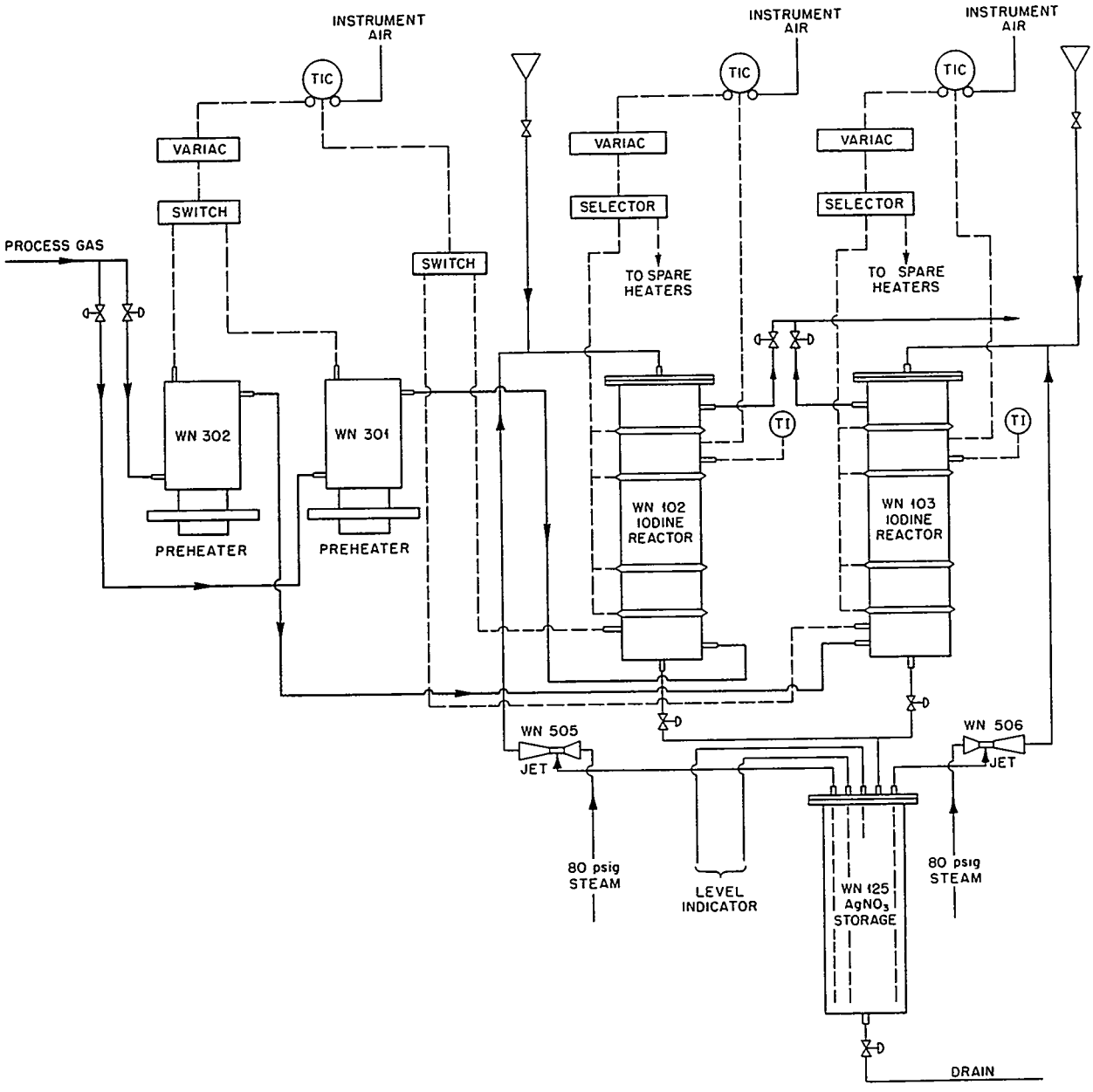
$$V = \frac{(\pi)(9.75)^2(10)(0.68)}{(4)\ (144)} = 3.53\ ft^3$$

$$\text{Residence time} = \frac{\text{volume}}{\text{rate}} = \frac{3.53}{4.0858} \times \frac{460+32}{460+375} \times \frac{11.84}{14.7} = 0.41 \text{ min.}$$

$$= 24.6 \text{ sec.}$$

[redacted]

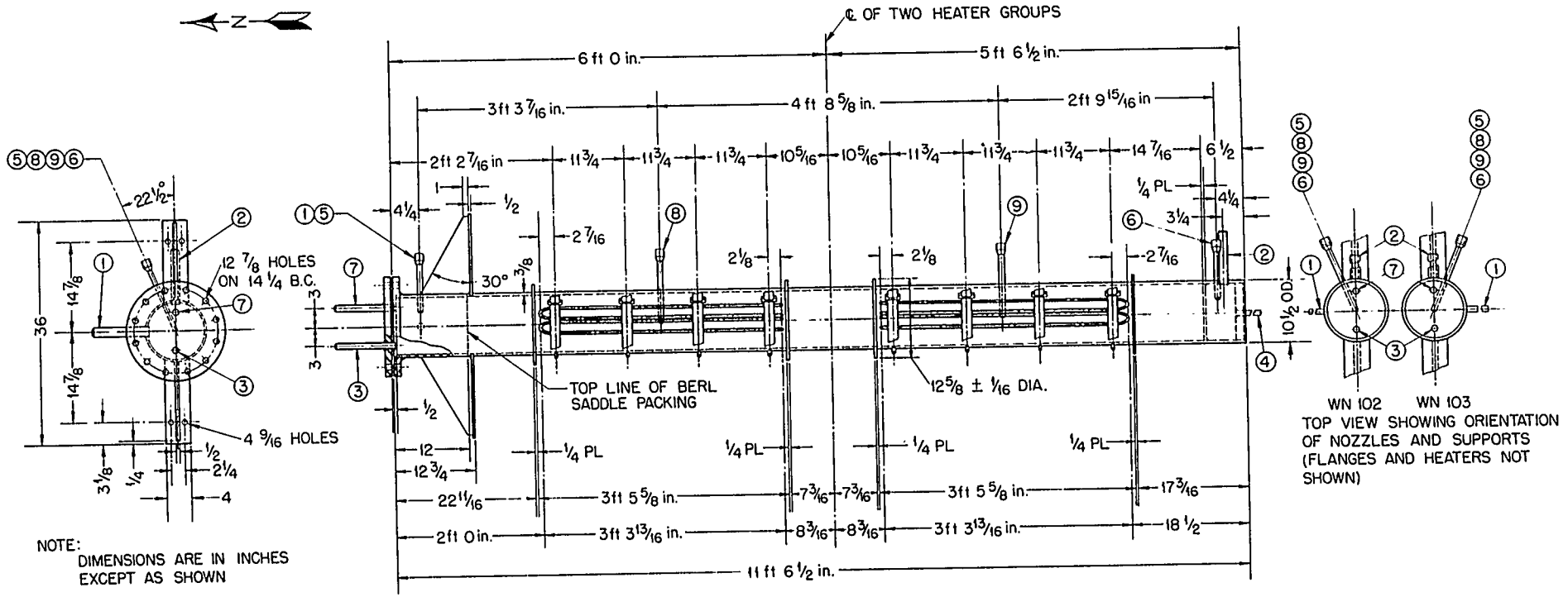
Drawing # 16984



SILVER NITRATE–IODINE REACTOR SYSTEM
FIG NO. 2

Drawing # 16985

1 1-in. BUTT WELDED GAS OUTLET
2 1-in. BUTT WELDED GAS INLET
3 ½-in. BUTT WELDED LIQUID INLET
4 ½-in. BUTT WELDED LIQUID OUTLET
5 ½-in. SCREWED TW
6 ½-in. SCREWED TW
7 ½-in. BUTT WELDED SPARE
8 ½-in. SCREWED TW
9 ½-in. SCREWED TW



NOTE:
DIMENSIONS ARE IN INCHES EXCEPT AS SHOWN

SILVER NITRATE--IODINE REACTOR
FIG. NO. 3

Off-Gas Processing From N.P. Fuel Element Dissolvings

Gases from NP fuel element dissolving will enter WN 102 and WN 103 having the following approximate composition (ORNL C.F. No. 51-7-90, ORNL C.F. No. 51-3-27 and ORNL C.F. No. 51-10-36):

Gas	lb. Moles per 7 NP Batches	Mole Percent	lb. Moles per hour*	CFM at 60°F. & 1 atm*
N_2 + A	1.6629	80.602	0.33258	2.1008
N_2O	0.1895	9.185	0.03790	0.2394
H_2	0.0235	1.139	0.00470	0.0297
CO	0.0024	0.116	0.00048	0.0030
O_2	0.1077	5.221	0.02154	0.1361
Radioactive				
I^{131}	4.207×10^{-8}			
Xe^{133}	1.388×10^{-8}			
Kr^{85}	1.599×10^{-5}			
Non-radioactive				
Br_2	8.529×10^{-6}			
Kr	3.106×10^{-4}	0.015	0.00006	0.0004
I_2	6.190×10^{-5}			
Xe	0.001904	0.092	0.00038	0.0024
Sub Total	1.9882		0.39764	2.5118
H_2O**	0.0749	3.630	0.01498	0.0946
Total	2.0631	100.000	0.41262	2.6064

The components which react with $AgNO_3$ are

I^{131} = 4.207×10^{-8} lb. moles = 8.414×10^{-8} lb. atoms
Non-radioactive Br_2 = 8.529×10^{-6} lb. moles = 1705.8×10^{-8} lb. atoms
Non-radioactive I_2 = 6.190×10^{-5} lb. moles = $12380. \times 10^{-8}$ lb. atoms

1.409×10^{-4} lb. atoms / 7 NP batches

$$Ag^+ + I^- \rightleftharpoons AgI$$
$$Ag^+ + Br^- \rightleftharpoons AgBr$$

*Based on 5-hour processing time. Design has been changed so that actual processing time is 7 hours.

** Saturation at 75°F

Since one atom of Ag is required for each atom of Br or I,

$$\text{Ag NO}_3 \text{ required} = (1.409 \times 10^{-4})(169.88) = \frac{0.02391 \text{ lbs}}{7 \text{ NP batches}} = \frac{10.85 \text{ gms}}{7 \text{ NP batches}}$$

The tentative processing rate for NP fuel elements is 6.4 batches per day. As determined above the effective $AgNO_3$ coating on the packing is 3.045 lbs. Therefore, the number of NP batches that can be processed before the coating needs regeneration is:

$$3.045 \text{ lbs. Ag NO}_3 \times \frac{7 \text{ NP batches}}{0.02391 \text{ lbs. AgNO}_3} = 892 \text{ NP batches.}$$

At a rate of 6.4 batches per day, the coating would be 99.9% effective for iodine removal for a period of

$$\frac{892}{6.4} = 139 \text{ days.}$$

Residence Time of NP Gases in WN 102 and WN 103

The operating conditions for off-gases from NP fuel element processing are the same as for MTR operation with the exception of gas velocity. If gases from one day's operation on NP fuel elements are processed in five hours, the rate is 2.6064 ft^3/min. measured at 60°F. and one atmosphere. For this case the residence time will be:

$$\text{Residence time} = \frac{\text{volume}}{\text{rate}} = \frac{3.53}{2.6064} \times \frac{460+60}{460+375} \times \frac{11.84}{14.7} = 0.68 \text{ MIN.} = 40.8 \text{ sec.}$$

However, it is expected that NP off-gas will be stored in WN 100 and WN 101 until a sufficient quantity is available for processing at the MTR off-gas rate of approximately 4 SCFM.

Regeneration of Ag NO_3 Coating

If all of the iodine and bromine fission products released during the dissolving reaction enter WN 102 and WN 103, it has been estimated above that the Ag NO_3 coating will remove these elements for 131 days of MTR assembly processing before any regeneration is needed. However, in actual operation there exists the possibility that the total amounts of these elements will never reach WN 102 and WN 103. By the best information, a portion of these elements will quite likely remain in solution in the dissolver acid. A second portion might be removed in the dissolver reflux condenser and a third portion might be dissolved in the caustic solution of the gas storage vessels WN 100 and WN 101. Consequently, it appears that the estimate of 131 days operation between regenerations is conservative. Nevertheless, sampling stations are provided whereby samples of gases entering and leaving WN 102 and WN 103 can be caught and analyzed for iodine activity. When an acitivity count of the exit sample indicates that less than 99.9% of the iodine is being removed, the $AgNo_3$ coating should be renewed.

4 M Ag NO_3 solution is pumped by a jet from WN 125 into the iodine reactor. The packing is allowed to soak in the Ag NO_3 solution for at least two hours to insure removal of the spent coating. The silver nitrate reactors should be cold during the regeneration to prevent excessive amounts of steam getting into other parts of the system due to evaporation of the Ag NO_3 solution. After draining, the system should be thoroughly dried by applying heat from the external heaters and passing nitrogen gas through the vessel.

Warm-up Time for WN 102 and WN 103

Since the packed section of the reactor is a rather good insulator, it can be expected that several hours will be required to raise the bed

temperature to operating temperature. The warm-up time is also lengthened by the fact that the vessel surface temperature is limited to 413.6°F., the melting point of the Ag NO_3 coating. Unsteady state heat transmission correlations for ceramic packing in cylinders was not available; however, with the aid of certain approximations the method described in Brown, Unit Operations, pages 430-431, can be applied with reasonable accuracy. This method concerns unsteady state heat transmission in long cylinders. Correlations have been made with the dimensionless groups

$$\frac{T_s - T}{T_s - T_o} \quad , \quad \frac{k\,\theta}{\rho C_p r^2} \quad , \quad \frac{k}{hr} \quad , \quad \frac{x}{r} \quad ,$$

where

T_s = surface temperature, °F. = 413°F.
T = bed temperature at any point at time θ, °F. = 375°F.
T_o = initial bed temperature, °F = 70°F.
x = distance from center of bed to point where T is measured, ft. = 0
r = radius of vessel, ft. = 4.875/12
θ = time, hrs.
ρ = density of bed, lbs/ft^3 = 45
C_p = specific heat of bed, BTU/lb - °F. = 0.2
h = coefficient of heat transfer between wall of vessel and bed, BTU/hr-ft^2 °F.
k = thermal conductivity of bed, BTU-ft/hr-ft^2 °F. needed to calculate θ

All of the quantities needed to calculate θ are known except h and k. These can be determined if certain approximations are made. If it is assumed that the heat transfer from the wall to the packing takes place chiefly by natural convection, the following equation for the heat transfer coefficient may be used:

$$h = 0.27 \left[\frac{\Delta T}{D}\right]^{0.25}$$ (McAdams, Heat Transmission, Equation 18, page 241)

h = heat transfer coefficient, BTU/hr-ft^2 $^\circ$F.
ΔT = temperature difference between surface and bed, $^\circ$F.
D = inside diameter, ft.

This equation strictly applies to gases being heated by natural convection outside of vertical cylinders. It is used here to approximate an h for the inside of a vertical cylinder. ΔT in the above equation is not constant. Initially

$$(\Delta T)_1 = 413 - 70 = 343^\circ F.,$$

and finally

$$(\Delta T)_2 = 413 - 375 = 38^\circ F.$$

$$(\Delta T)_{avg.} = \frac{343 + 38}{2} = 190.5^\circ F.$$

$$h = 0.27\left[\frac{(190.5)(12)}{9.75}\right]^{0.25}$$

$$= (0.27)(3.91)$$

$$= 1.05 \text{ BTU/hr-ft}^2\text{-}^\circ F.$$

The average thermal conductivity of the bed can be assumed to be an average of the k for Berl saddles and the k for air.

k = 0.02 for air
k = 1.8 for saddles
k_{avg} = 0.91

The values for the dimensionless groups can now be calculated:

$$\frac{T_s - T}{T_s - T_o} = \frac{413-375}{413-70} = \frac{38}{343} = 0.1107$$

$$\frac{k\,\theta}{\rho C_p r^2} = \frac{(0.91\,\theta)(144)}{(45)(0.2)(4.875)^2} = 0.612\,\theta$$

$$\frac{k}{h\,r} = \frac{(0.91)(12)}{(1.05)(4.875)} = 2.18$$

$$\frac{x}{r} = 0$$

From Fig. 416 of Brown,

$$\frac{k\,\theta}{\rho C_p r^2} = 3.2$$

$$0.612\,\theta = 3.2$$

$$\theta = 5.23 \text{ hours}$$

Heat Losses from WN 102 and WN 103

The iodine reactors are provided with Calrod heaters attached to the outside of the vessels to maintain a constant operating temperature. A thin metal sheath is placed around the heaters, and four inches of 85% Magnesia pipe insulation is placed around the sheath. The wall of the reactor and sheath will be at a maximum temperature of 413°F., and heat conducted through the insulation will be dissipated principally by radiation. An energy balance across the insulation shows that

heat conducted through insulation = heat radiated to surroundings.

The rate of conduction through the insulation is given by the equation

$$q_c = -k A \frac{dT}{dx}$$

q_c = heat transfer rate, BTU/hr.
k = thermal conductivity, BTU-ft/hr ft^2 °F.
A = area normal to heat flow, ft^2
T = temperature at any point x, °R.
x = distance along radius of vessel, ft.

The area normal to heat flow can be expressed in terms of the radius, x,

$$A = 2\pi x L$$

where L = length of vessel.

$$q_c = -2\pi k\, x\, L \frac{dT}{dx}$$

$$q_c \int_{x_1}^{x_2} \frac{dx}{x} = -2\pi k L \int_{T_1}^{T_s} dT$$

$$q_c \ln \frac{x_2}{x_1} = 2\pi k L (T_1 - T_s)$$

The following values can be assigned and the equation solved for Q_c:

k = 0.045 BTU-ft/hr ft^2 $^\circ$F
L = 11.542 ft
T_s = outer surface temperature
T_1 = 413°F. (inner surface temperature)
x_2 = 10.31 in.
x_1 = 6.31 in.

$$q_c = \frac{(2\pi)(0.045)(11.542)(873-T_s)}{\ln \frac{10.31}{6.31}}$$

The heat lost by radiation is given by the equation

$$q_r = 0.173\, A \epsilon \left[\left(\frac{T_s}{100}\right)^4 - \left(\frac{T_a}{100}\right)^4\right]$$

q_r = radiation loss, BTU/hr
A = radiating surface, ft^2
ϵ = emissivity
T_s = surface temperature, $^\circ$R.
T_a = temperature of surroundings, $^\circ$R.

The following values are known:

$A = \pi DL = (\pi)(20.625)(11.542) = 46.75$ ft^2
$\epsilon = 0.95$
$T_a = 70^\circ$F.

$$q_r = (0.173)(46.75)(0.95)\left[\left(\frac{T_s}{100}\right)^4 - \left(\frac{530}{100}\right)^4\right]$$

According to the energy balance, $q_c = Q_r$. Therefore,

$$\left(\frac{T_s}{100}\right)^4 - \left(\frac{530}{100}\right)^4 = \frac{(2\pi)(0.045)(11.542)(873-T_s)}{(0.173)(46.75)(0.95)\ln \frac{10.31}{6.31}}$$

$$\left(\frac{T_s}{100}\right)^4 - 790 = 753 - 0.863\, T_s$$

$$\left(\frac{T_s}{100}\right)^4 + 0.863\, T_s - 1543 = 0$$

By trial and error the surface temperature is found to be

$$T_s = 570^\circ R = 110^\circ F.$$

The total area of the radiating surface includes the cylindrical area (46.75 ft^2) used above plus the area of the two ends.

$$A_t = \text{cylindrical area} + \text{top flange area} + \text{bottom plate area}$$

$$A_t = 46.75 \frac{(\pi)(24)^2}{(4)(144)} + \frac{(\pi)(20.625)^2}{(4)(144)}$$

$$= 46.75 + 3.14 + 2.32$$

$$= 52.21 \text{ ft}^2$$

Since the temperature of the radiating surface is known, the total heat loss can be calculated:

$$q_t = 0.173 \; A_t \epsilon \left[\left(\frac{T_s}{100} \right)^4 - \left(\frac{T_a}{100} \right)^4 \right]$$

$$= (0.173)(52.21)(0.95) \left[\left(\frac{570}{100} \right)^4 - \left(\frac{530}{100} \right)^4 \right]$$

$$= 2320 \text{ BTU/hr}$$

$$= 0.68 \text{ KW}$$

Design Specifications of Ag NO_3 Solution Storage Vessel (WN 125)

The primary consideration for the Ag NO_3 solution storage vessel is that it must hold sufficient solution to fill either WN 102 or WN 103 above the top of the Berl saddle packing. For WN 102 and WN 103 the volume of the packed section has been determined to be 3.53 ft^3. The packing does not rest on the bottom of WN 102 but is supported 6-1/2 inches above the bottom. This volume must be added to the 3.53 ft^3 above.

$$V = 3.53\ ft^3 + \frac{(\pi)(9.75)^2(6.5)}{(4)(144)(12)}\ ft^3$$

$$= 3.53 + 0.29$$

$$= 3.82\ ft^3 \text{ actual solution volume}$$

The solution is to be transferred by steam jets WN 505 and WN 506 from the storage vessel to the reactors above. This transfer will necessarily cause dilution of the Ag NO_3 solution by condensing steam. Therefore, a freeboard volume must be allowed to accept the condensate. Using 80 psig steam, jet performance data indicate that 69 lbs. steam per hour will be consumed. Transfer of the 3.82 ft^3 of solution will be accomplished in approximately twelve minutes; therefore, only 13.8 lbs. condensate will be added to the Ag NO_3 solution during each transfer. It was decided to allow 2 ft^3 of freeboard volume to permit volume increase due to steam condensate; the total volume of WN 125 would therefore be 5.82 ft^3. The number of solution transfers before filling the vessel would be:

$$\text{No. transfers} = 2\ ft^3 \times 62.4\ \frac{lbs}{ft^3} \times \frac{1}{13.8\ lbs} = 9.04$$

If one regeneration is needed every 131 days, it should be

$$\frac{131 \times 9.04}{365} = 3.24 \text{ years}$$

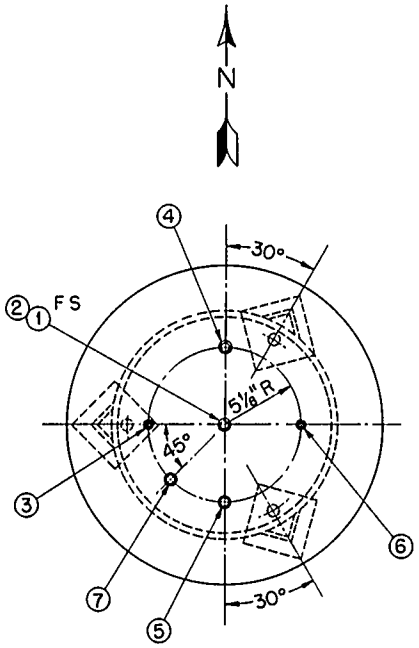
before WN 125 is filled with solution.

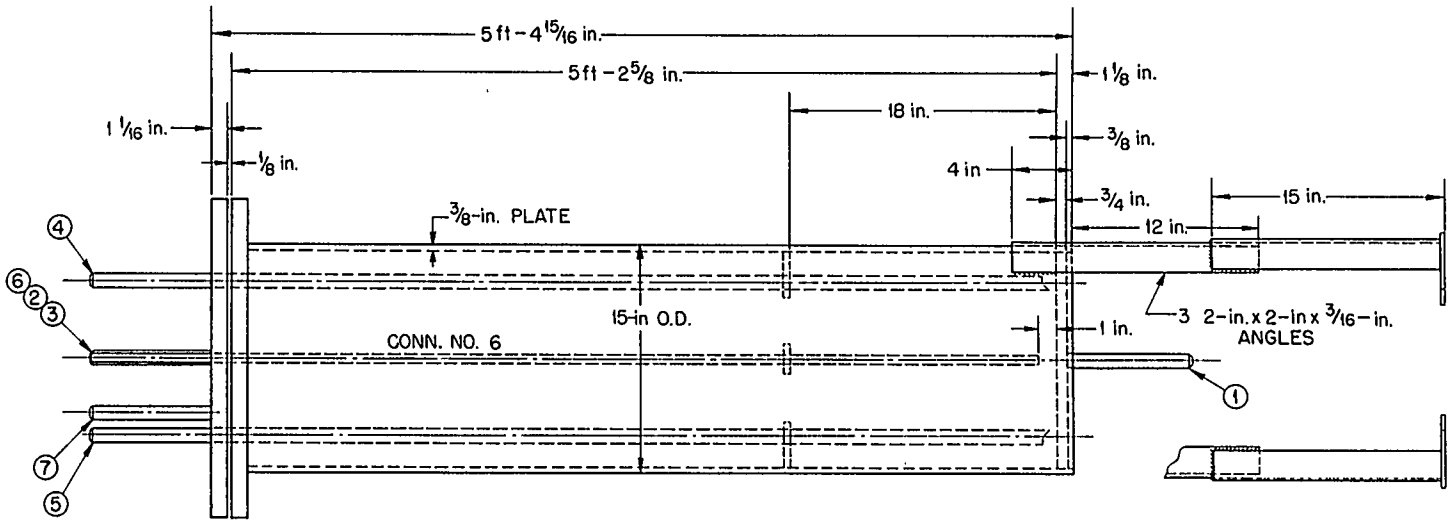
The most convenient arrangement would be to have WN 125 beneath WN 102 and WN 103 so that Ag NO_3 solution will drain by gravity to storage. For this reason it is desirable that WN 125 not be a tall vessel. Vertical installation would be desirable for ease of drainage as well as for ease of solution transfer by jets.

Complete construction details of WN 125 are given on ORNL Drawing No. 542-43V-2556B. For convenient reference pertinent dimensions are presented on the accompanying sketch Figure 4.

1 ½-in. DRAIN CONNECTION
2 ½-in. INLET CONNECTION
3 ¼-in. LI CONNECTION
4 ½-in. JET SUCTION CONNECTION
5 ½-in. JET SUCTION CONNECTION
6 ¼-in. LI CONNECTION
7 ½-in. VENT CONNECTION

NOTE:
ALL CONNECTIONS ARE BUTT WELDED





SILVER NITRATE STORAGE VESSEL WN 125
FIG. NO. 4

Design Specifications of Jets WN 505 and WN 506

The transfer of silver nitrate solution from WN 125 to WN 102 or WN 103 can be most easily accomplished by means of steam jet syphons. The jets can be located so that the suction lift is fifteen feet of silver nitrate solution which has a density of 92.5 lbs/ft^3 and a temperature of 70°F. The jet discharge head should be no more than 40 ft. At these conditions a Schutte Koerting Fig. 217 (1/2 in. suction and 3/8 in discharge) steam jet will syphon water at a rate of 207 gal/hr. However, since the silver nitrate solution has a higher density than water, the rate will be proportionally less.

$$\text{Ag NO}_3 \text{ solution rate} = 207 \times \frac{62.4}{92.5} = 139.7 \text{ gal/hr.}$$

There will be 3.82 ft^3 of solution to be transferred. The time required for this transfer will be

$$3.82 \text{ ft}^3 \times 7.48 \frac{\text{gal}}{\text{ft}^3} \times \frac{60 \text{ min}}{139.7 \text{ gal}} = 12.28 \text{ minutes.}$$

Subsequent transfers will require slightly longer periods of time because of volume increase due to steam dilution.

The jet construction should be of stainless steel.

Design Specifications of Preheaters WN 301 and WN 302

One preheater is to be installed in series with each of the iodine reactors. The purpose of these units is to raise the temperature of the gases from the storage drum temperature to the operating temperature of WN 102 and WN 103. Gases will enter the preheater at approximately 70°F and will leave at 375°F. A thermocouple located in the exit stream will actuate a variac controller which in turn will control the heat input to the unit.

Process gases from MTR assembly dissolvings will have a composition as indicated on page 8 . However, most of the radioactive and non-radioactive fission products appear in such small mole fractions that they may be neglected in calculating the energy requirements. The following gas composition is used:

Component	lb. Moles per 8 MTR Batches	Mole Fraction	Mean Molal Heat Capacity Between 70°F. to 375°F., C_{p_m}, BTU/lb. Mole -°F.
N_2+A	2.4840	0.7275	7.0
N_2O	0.4579	0.1341	10.2
O_2	0.2600	0.0762	7.0
H_2	0.0567	0.0166	6.99
CO	0.0059	0.0017	7.0
Kr	3.312×10^{-4}	0.0001	5.0
Xe	0.0020	0.0006	5.0
H_2O	0.1474	0.0432	8.4
	3.4142	1.0000	

The total heat required to heat the gas from 70°F. to 375°F. is given by the integral

$$Q = \int_{70}^{375} \left[N_1 C_{p_1} dT + N_2 C_{p_2} dT + \ldots + N_i C_{p_i} dT \right]$$

$$Q = (NC_p)_{N_2} \Delta T + (NC_p)_{N_2O} \Delta T + (NC_p)_{O_2} \Delta T + (NC_p)_{H_2} \Delta T + (NC_p)_{CO} \Delta T + (NC_p)_{H_2O} \Delta T$$

$$= \left[(2.4840)(7.0) + (0.4579)(10.2) + (0.2600)(7.0) + (0.0567)(6.99) + (0.0059)(7.0) + (3.312 \times 10^{-4})(5.0) + (0.0020)(5.0) + (0.1474)(8.4) \right] (375-70)$$

$$= (17.39 + 4.67 + 1.82 + 0.39 + 0.04 + \text{neg.} + 0.01 + 1.24)(305)$$

$$= (25.56)(305)$$

$$= 7800 \text{ BTU/8 MTR batches}$$

If these gases are processed in a five-hour period, the rate at which heat must be added is

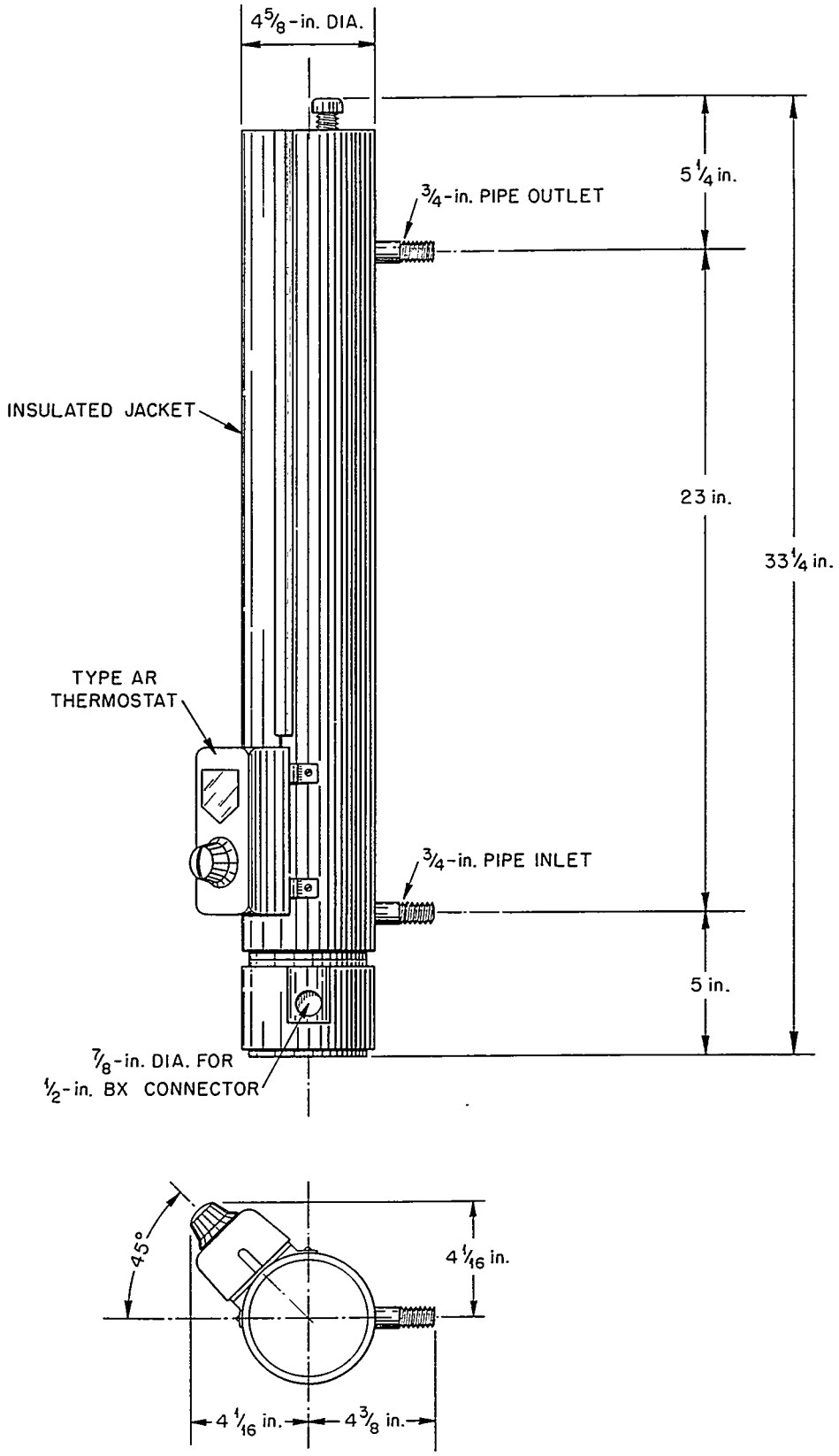
$$q = \frac{Q}{\text{time}} = \frac{7800}{5} = 1560 \text{ BTU/hr}$$

$$= 0.457 \text{ KW}$$

Figure 5 , page 28 , presents a sketch of Chromolax GCH-215 air preheater which will be satisfactory for this service. The rated capacity of this heater is 1.5 KW, which allows approximately a threefold safety factor above normal operation.

William L. Carter

W. L. Carter
Process Design Section
Chemical Technology Division



PREHEATER FOR $AgNO_3$-I_2 REACTOR

FIG. NO. 5

Silver Nitrate Storage Vessel
WN 125

Function:	Storage of 4 M silver nitrate solution
Description:	Vertical installation; cylindrical with flanged top and welded plate at bottom; supported by legs of 2" X 2" X 3/16" angle iron.
Capacity:	43-1/2 gals.
Vessel Data:	Design pressure - 80 psig & full vacuum Design Temperature - 212°F Operating pressure - 10" H_2O vacuum Operating temperature - 100°F
Material:	Shell and heads - ss 347 Pipe internals - ss 347 External bolting - ss 302 Gasket - teflon
Weight:	Empty - 520 lbs. Full Water - 882 lbs Full 4 M Ag NO_3 - 1058 lbs
Stress relieved:	No
Treatment:	Pickle and passivate
Reference drawing:	Foster Wheeler 542-43V-2556B
Fabricator:	Alloy Fabricators
Fabricator's drawing No:	A-1390-A-6
Bechtel Purchase Order No.:	1699-OR-139

[redacted]

Silver Nitrate - Iodine Reactor
WN 102 & WN 103

Function:	Contain silver nitrate coated Berl Saddles which remove iodine from process gas
Description:	Vertical installation; cylindrical with flanged top and welded plate at bottom; calrod tubular heaters strapped to outer surface; insulated with 85% Magnesia.
Capacity:	Total volume - 44.25 gals. Operating volume-31.83 gals.
Vessel data:	Design pressure - 80 psig & full vacuum Design temperature - 450°F. Operating pressure - 10" H_2O vacuum Operating temperature - 375°F.
Material:	Plate, shell and heads - ss 347 Pipe - ss 347 Gasket - ss 304
Weight:	Empty - 735 lbs. Berl saddles - 235 lbs. Silver Nitrate - 445 lbs. Total - 1415 lbs.
Insulation:	4 in. 85% Magnesia
External heaters:	General Electric Calrod, 230 volt, 4700 watts, 18-8 stainless steel sheath
Treatment:	Pickle and passivate
Reference drawing:	Foster Wheeler 542-41V-2551 A
Bechtel Purchase Order No:	1699-OR-139
Fabricator's drawing No:	A-1390-A-20
Fabricator:	Alloy Fabricators

[redacted] INFORMATION

[redacted]

Preheaters for Silver Nitrate - Iodine Reactor WN 301 & WN 302

Function:	Preheat process gas from storage temperature to processing temperature
Description:	Chromolax series 2 air preheater; vertical installation
Heater data:	Design pressure - 80 psig Design temperature - 1200°F. Operating pressure 10" H_2O vacuum Operating temperature -375°F
Electrical data:	115 volts, 1500 watts, single phase
Material:	Inconel
Weight:	35 lbs.
Reference:	Edwin L. Wieg and Company Catalogue No. 50 Chromolax type GCH-215, series 2.
Vendor:	Edwin L. Wieg and Company
Bechtel Purchase order No.:	1699-NY-542-476-BG

[redacted]

Reference Drawings and Sketches

1. Drawing 542-41P-1340C, WN System Flowsheet - North Cell
2. Drawing 542-41V-2551A, Silver Nitrate Iodine Reactor
3. Drawing 542-43V-2556B, Silver Nitrate Storage Vessel - WN 125
4. Sketch A, Side View, Proposed Heater Terminal for WN 102 and WN 103
5. Sketch B, Front View, Proposed Heater Terminal for WN 102 and WN 103
6. SKCR 183, Proposed Spacing of Calrod Heaters Showing Clamp and Retainers for Spacing Heater Elements
7. SKCR 184, Longitudinal Spacing of Heaters and Clamps
8. SKCR 185, Proposed Clamp for Heaters
9. SKCR 186, Section of Proposed Casing and Insulation for Calrod Heaters for WN 102 and WN 103
10. SKCR 187, Proposed Clamp Hinge and Locating Pin for Heaters for WN 102 and WN 103
11. SKCR 188, Dimensions for Calrod Heaters for WN Vessels
12. SKCR 189, Section of Proposed Casing at Terminal End of Heaters for WN 102 and WN 103

[redacted]

Bibliography

1. Brown, G.G., and Associates, Unit Operations, John Wiley and Sons, Inc., New York, (1950).

2. Carter, W.L., "Suggested Design of a Unit for the Removal of Iodine and Bromine from Arco Dissolver Off-Gas Stream", ORNL Report No. CF 51-3-27 to F. L. Culler, March 6, 1951.

3. Carter, W.L., "Off-Gas Material Flowsheets for the Idaho Chemical Processing Plant", ORNL Report No. CF 51-7-90 to F. L. Culler, July 19, 1951.

4. Carter, W.L., "Design Specifications and Operation Storage Vessel for Idaho Chemical Processing Plant Dissolver Off-Gas Stream", ORNL Report No. CF 51-10-36 to F. L. Culler, October 5, 1951.

5. Cooper, V.R., Hanford Engineering Works, "Iodine Removal with Silver Reactors", letter to L.C. Evans, E.I. duPont de Nemours & Co., Wilmington, Delaware, July 2, 1951.

6. Hougen, O.A., and Watson, K.M., Industrial Chemical Calculations, John Wiley and Sons, Inc., New York, (1936)

7. Lyon, A.M., "Decontamination of Waste Gases", Air Reduction Sales Company Report ARSC-25, June 14, 1949

8. Lyon, A.M., and McNabney, R., "Decontamination of Waste Gases", Air Reduction Sales Company Report ARSC-29, August 26, 1949.

9. McAdams, William H., Heat Transmission, McGraw Hill Book Company, Inc., New York, (1942)

10. McNabney, R., and Lyon, A.M., "The Removal of Iodine from Gas by Reaction with Silver in Packed Towers", Air Reduction Sales Company Report ARSC-28, August 16, 1949.

11. Wynn, C.S., and McNabney, R., "A Unit for Removal of Iodine from Hanford Dissolver Off-Gases", Air Reduction Sales Company Report ARSC-19, February 11, 1949.

12. Wynn, C.S., "A Unit for Removal of Iodine from Hanford Dissolver Off-Gases", Air Reduction Sales Company Report ARSC-20, April 6, 1949.

[redacted]